APPENDIX B

SELECTED AG NOTES FROM MONTANA STATE UNIVERSITY EXTENSION SERVICE

http://scarab.msu.montana.edu/Agnotes

?? Ag Note No. 51: Some Guidelines for Irrigating With Saline Water

?? Ag Note No. 67: The Erosion Process How It Happens

?? Ag Note No. 71: Acceptable Irrigation Water Quality

?? Ag Note No. 72: Understanding Saline and Sodic Soils

?? Ag Note No. 73: Soil Quality and Water Quality Texture Salinity Sodium Water

?? Ag Note No. 116: Management of Saline and Sodic Soils Gypsum, Sulfur, and Other Myths

?? Ag Note No. 137: Salt Problems Common in Some Soils of Montana

?? Ag Note No. 146: Suitability of Water for Livestock

?? Ag Note No. 155: Some Guidelines For Irrigating With Saline Water

?? Ag Note No. 170: Soil Salinity Crop And Forage Tolerances

SOME GUIDELINES FOR IRRIGATING WITH SALINE WATER AGRONOMY NOTES NO. 51

http://scarab.msu.montana.edu/Agnotes/category_167.htm

The quality of water from Montana's rivers and streams generally decreases as the irrigation season progresses. Historic records indicate that sediment load is usually heaviest during the May and June snowmelt runoff periods and as the sediment load decreases and stream volumes decrease, the salt level of most rivers and streams increases. This is particularly true to the streams and rivers east of the Continental Divide. With that being the case, a few guidelines for irrigating with salty water might prove useful for irrigators -especially those using water from the Powder, Milk, Marias, Tiber, Musselshell, Tongue Rivers and secondary tributaries to the Missouri and Yellowstone Rivers.

Irrigating with saline (salty) water. The smaller rivers that supply most of the irrigation water for the eastern two-thirds of Montana are interesting -the saline and volume change dramatically during the year. Review of the historic water quality and flow records indicate several changes through the year. Knowledge of these changes may be of some value in attempting to "get the most" our of the available irrigation water.

?? Fill the profile as early as possible after the peak flood stage or as soon after harvest as possible, if you are harvesting forages (hay, alfalfa). The sediment and salinity levels tend to increase beginning early in the spring as runoff begins. Salinity level peaks and then starts to decrease as dilution takes over, while sediment continues to increase. During the high flow period salinity is low, but sediment is high. Sediment generally tends to start decreasing dramatically after the peak.

?? If at all possible, delay irrigation until after the peak flow period, as the flow level begins to drop. Salinity and sediment tend to be lower at this flow rate on the "down" or falling stage than the same stage on the "up" or rising level part of the cycle.

?? Some sediment in the water will help move the advancing wetting front across border-dike, graded border, basin, and furrow irrigated fine sandy loam soils.

Salinity (or salt load) is best determined by measuring the TDS (total dissolved solids) or EC (electrical conductivity). The TDS varies from as low as only a few hundred parts per million (or milligrams per liter), to as much as 2500 to 3000 parts per million (mg/l) during the lowest flow periods in some of the smaller streams of eastern Montana. The lowest TDS usually occurs when the river level has risen to its maximum and is then falling. When the river goes through rising and falling stages due to rain (especially thunderstorms), the TDS is usually lower at a given river level when the level is falling, rather than rising.

Irrigation strategies to reduce salt load. If possible, when irrigating in the spring and early in the irrigation season, fill the profile with water of low TDS/EC. The EC of the water will generally be between 0 and 9 mmhos/cm (equal to 9000 micromhos/cm). To convert this value to an approximate TDS (total dissolved solids), multiply the EC in mmhos/cm by 640. The result will be an approximate TDS in milligrams per liter. The soil will tend to concentrate salt during the irrigation season and thus have an EC greater than the irrigation water. In well-drained soils, the EC will be about the same all the way through the root zone, while on poorly drained soils, the EC will generally increase dramatically with depth. Young plants and seedlings are much more sensitive to EC of both the irrigation water and soil than established plants. Once the EC gets above about 2.4 mmhos/cm in the soil, plants will begin to show signs of stress -stress that looks just like drought.

Irrigation strategies to reduce salt injury to seedlings. On new plantings of alfalfa, grass, other legumes, small grains, corn, and sorghum, shorten the length of time or your sets early in the season, when plants are still small, and irrigate just a little more frequently. You'll pump just the same amount of water as before, but get a better stand, better early growth, and an increase of as much 25% in overall yield. In addition, the irrigation water will tend to have slightly less dissolved salt this time of the season.

Use of saline water for irrigation. The following is a summary of an article by J. D. Rhoades, soil scientist with the U.S. Salinity Lab in Riverside, CA. The article first appeared in the October 1984 issue of California Agriculture. Saline water, or water which is generally classified as having too much dissolved salt for irrigation, can often be used successfully without hazardous long-term effects on the crops or soils. However, certain conditions need to be met:

?? The soil being irrigated must be well-drained

?? Salt tolerant crops (established alfalfa, barley, sorghum, sudan grass, sordan) should be the primary crops grown

?? Rotations should be planned to provide for a sequence of progressively more salt tolerant crops

?? Salts should be leached out of the soil in the spring or winter

?? As the salinity of either the irrigation water or soil solution increases (with prolonged crop water use and through the irrigation season), the volume of irrigation water applied should be progressively increased.

As Rhoades points out, adoption of new crop and water management strategies can further facilitate the use of saline water for irrigation. One strategy is to substitute more saline water (later in the irrigation season) for good quality water to irrigate certain crops in the rotation or well-drained soils. Whatever salt buildup that might occur in the sol from irrigating with salty water can be reduced in the following winter or spring from rainfall or irrigation with low-salinity irrigation water.

Soils do not usually become excessively saline from use of saline water in a single irrigation season. It may even take several irrigation seasons to affect the level of salt in the soil solution. The maximum soil salinity in the root zone that results from continuous irrigation with saline water does not occur when salty water is used only a fraction of the time.

For purposes of comparison, Colorado River irrigation water has a TDS of about 900 ppm, while the rivers of central and eastern Montana generally ranges from about 750-1,500 ppm during the irrigation season. Drainage water TDS will usually be 3,500 to 4,500 ppm.

THE EROSION PROCESS HOW IT HAPPENS AGRONOMY NOTES NO. 67

http://scarab.msu.montana.edu/Agnotes/category_96.htm

Every time a raindrop hits a bare, unprotected soil surface, it is like a miniature version of a huge boulder being dropped from an airplane onto a pile of smaller rocks. The blasting action of falling rain both loosens some soil particles and packs others. Then it floats away some of the loosened particles.

Naturally, if the raindrop hits a piece of plant residue, expending its energy that way, the water from the raindrop just trickles down to the soil; no blasting and very little packing. Admittedly, there's still an opportunity for the raindrop -and many others like it -to float off some soil particles, but they don't usually go far or pick up much soil before they hit one of the many little dams created by residue and debris on the soil surface of fields where residue has been left after harvest.

Water Erosion—The Process

Sheet erosion is the process, when a uniform later of topsoil is skimmed from the surface by flow of water from either rainfall or melting snow. This is the least noticeable kind of erosion. The only time it gets noticed is when the eroded soil settles out in a low spot and silt, the soil particle most often moved by sheet erosion, at least partially buries emerging crops or other vegetation.

Rill erosion occurs when flow from rain or melting snow forms little streams as the water heads down hill, cutting small gullies as it goes. This is a more noticeable kind of erosion, but one which is quickly covered over again by the next tillage operation. Rill erosion can -and often does -occur for years without attracting attention from farm operators. However, it is a signal that this particular type of soil is quite easily eroded. The soil surface needs protection -either permanent cover or use of conserving practices such as conservation tillage -or long-term productivity will begin to diminish. And, research has clearly shown that it is no easy or short-term process to restore this productivity, especially on knolls, hilltops, and hillsides.

The most noticeable kind of erosion is where actual gullies are cut by flowing water. Gaps too wide and deep to cross with farm equipment can develop during extremely heavy rains. Generally, drastic measures are needed to solve this problem -permanent grass waterways, permanent cover crops.

The Wind Erosion Process—Montana's Major Concern

Wind can carry soil particles from unprotected soil, just as water can. Just like the dust in front of your truck or tractor tires and the dust behind you as you cross a field, turbulence similar to that occurs when wind starts sweeping across unprotected fields. When an air current gets a straining shot at a particle of soil, that particle can be lifted by the energy in the wind, perhaps dislodging some others as it becomes airborne. Fertilizers, herbicides, and insecticides, either chemically attached to the soil or free among the soil particles -can be moved right along with the soil materials.

Conservation tillage is probably more effecting in countering the action of wind erosion that it is in deterring water erosion. Even a rough soil surface helps break the velocity of air currents at ground level. Residue does an even more efficient job since the surface of stalks and stubble can't be lifted to knock loose others.

Naturally, different soil types and degrees of slope affect erosion potential of unprotected soil. In addition, soil moisture, previous crop, period of the year, and the general openness and position in the landscape all have a bearing on how much soil can be pried loose by water and wind.

Soil which has been loosened by freezing and thawing and wetting and drying action tends to be more easily eroded in the spring; that's when most rainfall occurs, also. Later in the season, after the soil has been packed by rainfall, it is usually less subject to erosion. This is also when crop cover is often present to protect the soil surface. Needless to say, conservation tillage practices -those which leave some crop residue on the soil surface during the non-cropping period, can help reduce erosion by wind and water -both by absorbing some of the energy and by slowing the movement of soil once it begins.

ACCEPTABLE IRRIGATION WATER QUALITY AGRONOMY NOTES NO. 71

http://scarab.msu.montana.edu/Agnotes/category_169.htm

NOTE: During the next month I will be presenting a series of four notes dealing with irrigation water management, irrigation water quality, and soil quality related to irrigation management. There is a water quality component to this series. Throughout the winter I will continue to concentrate efforts on several specific subjects and topics -a new one each month. If you have specific agronomy -related issues you wish to see addressed, please let me know. If I can't find the text resources, I will contact some of the other specialists or do a WEB search to see what I can find for you.....

Seasons Greetings -early.....

Irrigators could benefit by periodically sampling and testing their irrigation water. Although soil testing will provide a general guideline of the effect irrigation water might be having on soil quality, the chemistry of the soil will only reflect the chemical content of irrigation water after several cropping seasons. Irrigators should realize that groundwater quality can change with time and surface water quality changes seasonally; surface water tends to become more saline as stream flow declines. If an irrigator is going to sample water for testing, the sample should be collected after the well or supply has been pumped for some time and the sample should be placed in a clean container.

Table 1 provides a summary of the limitations that might be associated with irrigation water. The most important qualities to consider are the electrical conductivity (EC), which is a measure of the amount of dissolved salts; the pH, which is a measure of the acidity; and the adjusted sodium adsorption ratio (SAR), which is an index of the relationship between the concentration of sodium and calcium and magnesium. (Another measure of salinity is the total dissolved solids (TDS), which can be estimated from the EC by multiplying the EC value in mmhos/cm by 640).

Salinity generally has more of an adverse effect on the crop than on the soil being irrigated. Most crops have some degree of sensitivity to salt, because of the competition for water. In addition, some constituents of dissolved salt can sometimes be toxic to plants in high concentrations. Sodium, on the other hand, can have an adverse effect on soil permeability. Heavy-textured soils and sprinkler-irrigated soils have the greatest sensitivity to permeability hazard from sodium in irrigation water.

Irrigation water that is suitable for one soil may not be suitable for another soil. Sodium affects clayey soils more than it affects sandy soils. Soluble salts are leached from sandy soils more readily than they are leached from clayey soils.

Guidelines for interpretation of irrigation water quality:

Limitation	Acceptable	Increasing	Severe Problem
------------------Range of EC (mmhos/cm) -------------------			
salinity (affects crop growth)	<0.75	0.75-3.0	>3.0
-------------------Range of TDS (mg/l or ppm)---------------			
	<480	480-1920	>1920
--------------------Range of EC (mmhos/cm) --------------------			
permeability (affects infiltration and drainage)	>0.5	0.2-0.5	<0.2
-------------------Range of TDS (mg/l or ppm)---------------			
	>320	130-320	<130
-------------------Range of SAR (adjusted)--------------------			
	<8	8-16	>16

Suggested range in irrigation water EC and SAR for different soils:

	EC Range (mmhos/cm)		SAR Upper Limit	
Soil Texture	**Flood**	**Sprinkler**	**Flood**	**Sprinkler**
Very coarse (sands, loamy sands)	0-4	0-5	18	24
Coarse (sandy loam)	0-3	0-4.5	12	15
Medium (loams, silt loams)	0.2-2.5	0-3	12	15
Medium fine (clay loam, sandy clay loam)	0.3-2.5	0.2-3	8	12
Fine (silty clay loam, clay, sandy clay, silty clay)	0.5-2	0.3-2.5	6	9

UNDERSTANDING SALINE AND SODIC SOILS AGRONOMY NOTES NO. 72

http://scarab.msu.montana.edu/Agnotes/category_289.htm

Salinization of soils is common in Montana. Although salinization occurs naturally, without careful management of either irrigated and dryland soils, it is possible for salinization to increase. At present, more than 280,000 acres of land in Montana are characterized as sodium or salt-affected. Understanding saline and sodic soils, their causes and management will help land managers reduce their incidence in the future.

Where does salt come from? All waters and parent rock contain some salts. The amount of salt is dependent on several factors, the most important being the parent material, the conditions under which the soil formed, the drainage of the soil, and the predominant weather conditions. The term saline refers to more than just sodium or chloride. Such ions as magnesium, calcium, carbonate, bicarbonate, and sulfate can all contribute to salinity. As water evaporates from a soil surface or is used by plants, the salts in the water are left behind. This causes salt to accumulate in the soil. If this salt accumulation is not balanced or offset by downward leaching, due either to rainfall or irrigation, salinity will occur. If the predominant ion is sodium, then the soil can also be sodic.

Where do saline and sodic soils occur in Montana? The most common locations to find saline soils are in the eastern and central part of Montana and in poorly drained areas north of the Missouri River. Naturally saline soils are found along many stream terraces and bottoms, while saline seeps can be found throughout most of the glaciated plains region. Sodic soils are unlike saline soils, although they occur in many of the same locations and can form together. Sodic soils are most common in eastern and north central Montana and along irrigated flood plains of many rivers.

Saline soils contain excess soluble salts, which make it difficult for plants to take up water and nutrients. A saline soil (see Table 1) has an electrical conductivity (EC) more than four mmhos/cm. Saline soil causes spotty bare areas in a crop field, due to poor emergence. In severe cases, the soil will have a white residue at the surface. Irrigated saline soils can be improved by leaching and good drainage. Dryland saline seep areas can be reclaimed by planting deep-rooted perennials such as alfalfa, sweet clover, and grasses in the recharge areas.

Sodic soils contain excess exchangeable sodium; this sodium is not harmful to plants, but it does make fine-textured soil extremely impermeable to water and difficult for roots to penetrate. Sodic soils have an exchangeable sodium percentage (ESP) more than 15% or a sodium adsorption ratio (SAR) more than 12. Sodic soils generally occur as localized pan spots. The subsoil of sodic soils is usually very compact, moist, and sticky and is composed of soil columns with rounded caps. To improve sodic soils, the sodium must be replaced with calcium and the sodium leached from the soil. Hence, it is not possible to reclaim a sodic soil without good drainage. The sodium can be replaced by adding calcium in the form of gypsum or calcium chloride or by adding materials which will release the calcium already present (sulfur, sulfuric acid, organic matter).

Saline-sodic soils have both excess soluble salts and exchangeable sodium. To improve these soils, amendments and drainage are essential. Leaching a saline-sodic soil without amendments will result in a sodic soil and may worsen the soil structure.

TABLE 1
CONDITIONS OF SALINE, SODIC, AND SALINE-SODIC SOILS

Soil condition	EC (mmhos/cm)	ESP (%)	SAR
Saline	>4	0-15	0-12
Sodic	0-4	>15	>12
Saline-sodic	>4	>15	>12
Non saline, non sodic	0-4	0-15	0-12

Things to remember: saline soils -the problem is lack of available water to plants and toxicity; the solution is leaching and improved drainage. Sodic soils -the problem is poor soil structure, drainage, and impermeability; the solution is addition of soil amendments and improved drainage. Saline-sodic soils -the problem is lack of available water, and poor drainage; the solution is addition of amendments, leaching, and improved drainage.

How do I know if the problem is there? Often the problem is obvious. The presence of a permanent or seasonal high water table will often be a sign of saline or sodic soils. Poorly drained potholes in glacial landscapes often have localized areas that have temporary high water tables. Excess soluble salts will often crystallize on the surface of fallow fields. Thick continuous crusts form in saline seeps. Thin patchy salt crusts will form under clods or on the shady side of clods where marginal salt problems are found. Patterns of growth in cropped fields will be poor, spotty stand establishment. Saline soils tend to inhibit germination and emergence of cereal grains. Under severe salt stress, herbaceous crops appear bluish-green; leaf tip burn and die-off of older leaves in cereal grains can result from salinity or related drought stress.

SOIL QUALITY AND WATER QUALITY TEXTURE SALINITY SODIUM WATER—AGRONOMY NOTES NO. 73

http://scarab.msu.montana.edu/Agnotes/category_290.htm

Every once in a while someone calls me with a question that is worth either repeating, sharing, or expanding on. One example is the following. I received a call from a lady asking me how much water she should be irrigating with. Well.... the answer is sort of long and drawn out and complicated -you know, that depends on a lot of different factors. But, before we finished our conversation, I offered her what turned out to be one good piece of advice. The question turned into an answer like the following: The available water-holding capacity of a soil is a function of the texture. How much water the soil can actually hold (or how much of the water which is being applied) depends on both the water holding capacity and just how dry the soil is when the water is added. As an example, the following table illustrates the Available Water Holding Capacity of Soils. This is the amount of water that would and could be made available to plants after the soil had been irrigated:

Soil Texture	Inches of Water Per Foot of Moist Soil
Sands and fine sands	0.75
Very fine sands, loamy sand	1.00
Sandy loam	1.50
Loam	1.90
Silt loam, silt	2.20
Silty clay loam	1.90
Clay loam, sandy clay loam	1.70

She then started asking questions about all the terms that appeared on her water test report. Like, what is EC, SAR, ESP, and Conductivity. So.....

Conductivity (also referred to as EC, electrical conductivity) -an index of the dissolved solids concentration. Usually presented in either micromhos/cm or millimhos/cm. Low salinity water is water with a conductivity between 0 and 250 micromhos/cm (0.25 mmhos/cm). Low salinity water can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop, as long as there is good drainage. Some leaching is required (rainfall will generally be enough), but this occurs under normal irrigation practices.

Medium salinity water has a conductivity between 250 and 750 micromhos/cm (0.25-0.75 mmhos/cm). This water can be used if a moderate amount of leaching occurs as a result of the combined effects of irrigation and rainfall. Plants with moderate salt tolerance can be grown -grasses do well.

High salinity water has a conductivity between 750 and 2250 micromhos/cm (0.75-2.25 mmhos/cm). This water should not be used on any soils with restricted drainage or where excessive water is not available for continuous leaching. Special management for salinity control is necessary with this water.

Needless to say, water with salinity above 2250 micromhos/cm is very saline and should not be used for irrigation. This water is only occasionally suitable, where excess leaching with good-quality water will follow. As for SAR -the Sodium Adsorption Ratio -this is (generally speaking) the ratio of the amount of sodium to the amount of calcium and magnesium. Ideally, this number should be small. Low-Sodium water is water with an SAR less than 10. This water can be used for irrigation on almost all soils with little danger of development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees may accumulate injurious concentrations of sodium.

Medium Sodium water is water with an SAR between 10 and 18, and this water can present appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low leaching conditions, unless gypsum (calcium carbonate, which is common in most Montana soils) is present. This water may be used on coarse-textured or organic soils with good permeability.

High Sodium water is water with an SAR between 18-26. This water may produce harmful levels of exchangeable sodium in most soils and will require special soil management -good drainage, high leaching, organic matter additions, gypsum additions.

The following table helps categorize each of the water qualities:

Salinity Hazard				
EC (micromhos/cm)	Low	Medium	High	Very High
	100-250	250-750	750-2250	>2250
Sodium Hazard				
SAR	0-10	10-18	18-26	>26

MANAGEMENT OF SALINE AND SODIC SOILS GYPSUM, SULFUR, AND OTHER MYTHS—AGRONOMY NOTES NO. 116

http://scarab.msu.montana.edu/Agnotes/category_292.htm

Here is one of those notes which came about because one of the subscribers of Agronomy Notes -Steve Ostberg, up in the Fairfield area, sent me some information about a soil sample and wanted to know the diagnosis'. As I recall, the soil sample had a pH about 8.5 or so and the EC (electrical conductivity) was about 15 millimhos/cm. Generally, when a soil sample is submitted to a lab for testing, pH and conductivity, salinity, or conductance are standard background measures. In this case, the background measurements provided some very valuable information.

Based on the information Steve provided me, I diagnosed the soil as "saline-sodic", meaning that it had both a high salt content and it was saturated with respect to sodium. Sodium, calcium, and magnesium are the cations or positively charged molecules which generally predominate the surface of the soil. Productive, non-problem soils generally will have a pH between 6.5 and 8.2, an EC less than 1.0 millimhos/cm, and less than 15% sodium saturated. This soil sample had everything going wrong for it. So... Steve asked -can I add gypsum or sulfur to this soil to address the problem, i.e., will gypsum or sulfur correct the salinity-sodicity problem?

My response to Steve was as follows:

.....You asked about applying sulfur or gypsum to the soil which was tested as alkaline and saline (saline-sodic, as I recall). The answer: Adding either gypsum or sulfur to this soil won't likely do much good!

Gypsum is generally added to provide either a calcium source to displace the sodium or a sulfur source that will enhance acidification of the soil. (Gypsum is calcium sulfate, 22.5% calcium). Sulfur is added as a sulfur source -at high rates as an amendment and at low rates (10-40 pounds per acre) as a plant nutrient. When the soil is alkaline (or basic, pH greater than about 8.2), sulfur is sometimes added because sulfur serves to stimulate microbial action, the release of hydrogen ions, and the formation of sulfuric acid in the -thus causing a lowering of the pH and along with that an exchange of divalent cations (calcium, magnesium) for sodium.

For most soils in Montana east of the continental divide, the soil is already saturated with respect to calcium (carbonate). Hence, addition of more gypsum simply drives the solution reaction more to precipitation. Kind of like having a glass of water which is saturated with sugar and adding another teaspoon of sugar -sugar crystals form almost instantly on the bottom of the glass. When you add gypsum (a source of calcium) to a soil already saturated with respect to calcium, you are just elevating the concentration of calcium and hence pushing more precipitation of calcium carbonate. In contrast, when you add sulfur, there is a very good chance of acidification and release of hydrogen, which will cause formation of sulfuric acid and a displacement of the sodium -which will then be replaced by calcium. However, without adequate drainage and good water to move the sodium out of the soil, little reclamation is to be gained by adding sulfur.

Basic rule -when you are attempting to reclaim either a saline, sodic (sodium saturated) or saline-sodic soil, the first thing you need is good drainage -an outlet to send the sodium to when it is displaced. The next thing is a source of calcium (already in the soil), and exchange process, and finally, a source of water to flush the sodium from the system.

Bottom line -seldom will gypsum or sulfur make much difference in our soils, unless it is an isolated situation and drainage is available. You might get a short-term, surface response to sulfur -which could be because of a temporary lowering of the pH, the release of some sodium, and temporary improvement of soil structure, but this is generally only temporary. You are better off to attempt to increase organic matter levels by continuous cropping, minimize tillage, establish plant species, which will tolerate the salinity and remove some of the water. With time, a good reclamation program which is focused on plant selection, salt tolerance, and re-vegetation while cutting off the source of water is much more effective and sustainable than use of gypsum or sulfur.

Another interesting question: About nitrate concentrations in the soil. A gentleman called me the other day and asked what was the significance of soil nitrate concentrations of 10,000 parts per million. Yes! I couldn't believe it at first either. But, he explained that it was the result of some munitions processing in the past. He wanted to know if plants would grow there and what target soil concentration he should shot for. I looked in every book I had and the highest soil test nitrate concentrations I could find were in the range of 200 ppm. My recommendation: try to get the soil test level down to 400 ppm. Under the present conditions, nitrate-nitrogen is about 1% of the soil composition. And the likely problems -nitrate toxicity, excessive vegetative growth, and highly saline soil.

SALT PROBLEMS COMMON IN SOME SOILS OF MONTANA AGRONOMY NOTES NO. 137

http://scarab.msu.montana.edu/Agnotes/category_293.htm

Some time ago, I recall sending out a piece of information on Critical Soil Test Levels -addressing nutrient levels and some other parameters, such as organic matter, cation exchange capacity, electrical conductivity, and sodium adsorption ratio. With this note, I thought I might add a little more information about the issue of salinity and sodicity in Montana soils. Generally, there are several terms which are used interchangeably to describe salty soils -a practice which is technically incorrect. For instance, salinity, sodicity, alkalinity are all different conditions of the soil.

Salinity is a measure or index of the total amount of soluble salt in the soil or soil solution -all kinds of salts. Generally calcium, magnesium, and sodium salts; carbonates, sulfates. The standard measurement for salinity is the EC -electrical conductivity. Seldom (unless a very high water table or very inadequate leaching with poor quality water) will this be a problem on sandy or gravelly sites. Most common on silt loams, silty clay loams in areas of low rainfall (<14 inches per year). The following table provides a summary of the common conditions associated with saline soils.

Conductivity (EC), rating, and tolerant crops and plants:

?? -2.0 mmhos/cm; OK; all vegetables and crops

?? -4.0 mmhos/cm; slightly salty; beans, foxtail, barley, some clovers, radish, celery

?? 4.0 -8.0 mmhos/cm; moderate; cereals, alfalfa, clover, grass, most vegetables except radish, celery, green beans

?? 8.0 -16.0 mmhos/cm; strong; barley, beets, wheatgrass, wildrye, trefoil, fescue

?? 16.0 -+mmhos/cm; excess; very little -saltgrass

Sodicity refers to the degree to which the soil exchange capacity and sites are saturated or occupied with sodium ions (as compared to the more preferred calcium and magnesium ions). Sodium, a common component of you detergents and laundry soaps, is a dispersing agent. Hence, soils which are saturated with sodium tend to be very difficult to work with -little aggregation, sometimes consolidated and blocky, poorly drained. These are the soils we often refer to as "gumbo". The best indicator of sodicity in a soil is the SAR -the sodium adsorption ratio, which is a relative comparison of the amount of sodium compared to calcium and magnesium. Generally, soils with SAR greater than 15 are considered sodic. The most common way to deal with sodic soils is to add another cation, calcium or magnesium, to displace the sodium. But good drainage is essential. Alkalinity is the third term we often hear -technically it refers to the acidity of the soil. Soils which are basic (as compared to those which are acidic) are considered to be alkaline. The parameter most often used to determine the alkalinity of a soil is the pH. Soils with pH greater than about 8.7 are considered to be alkaline. Alkalinity is another one of those issues commonly associated with poorly drained sites. Hence, before any action can be taken to lower the pH, good drainage must be insured. Then, ample additions of organic matter, increased cropping intensity, or large amounts of sulfur can be used to lower the pH and create more acidic conditions.

So, the question becomes -can I have a soil with all of these conditions at the same time? And the answer is -YES - but not likely.

SUITABILITY OF WATER FOR LIVESTOCK AGRONOMY NOTES NO. 146

http://scarab.msu.montana.edu/Agnotes/category_190.htm

Back in February, I received a call from Chet Hill, Roosevelt County Extension Agent in Culbertson. Apparently, a rancher in Roosevelt County was having some problems with livestock watering and wanted to know what was suitable water quality for livestock. A little digging provided some good information, which I thought I would share as summer gets closer. Most of my references are readily available and I have noted them here.

Some of the information here comes from a new bulletin of MSU Extension Service, EB 150, "Soil, Plant, and Water Analytical Laboratories for Montana Agriculture" (replacing Bulletin 1349), is now available through County Extension Offices or the MSU Publication Office at 406-994-2099 or by e-mail at ACXTB@MONTANA.EDU or VELTKAMP@MONTANA.EDU. One of the issues addressed in this bulletin offers the following guidelines about water quality suitable for livestock:

FROM TABLE 10
DRINKING WATER QUALITY STANDARDS FOR LIVESTOCK SUITABILITY.

Aluminum (Al)	5 ppm (milligrams/liter)
Arsenic (As)	0.2 ppm
Boron (B)	5 ppm
Cadium (Cd)	0.05 ppm
Chromium (Cr)	1 ppm
Cobalt (Co)	1 ppm
Copper (Cu)	0.5 ppm
Fluoride (F)	2 ppm
Lead (Pb)	0.05 ppm
Mercury (Hg)	0.1 ppm (Note: USDA lists 0.01 ppm)
Nitrate+Nitrite	100 ppm
Nitrite	10 ppm
Selenium (Se)	0.5 ppm (Note: USDA lists 0.05 ppm)
Vanadium (V)	0.1 ppm
Zinc (Zn)	24 ppm
Total Dissolved Solids	10,000 ppm
Magnesium + Sodium sulfates	5,000 ppm
Alkalinity (carbonate + bicarbonate)	2,000 ppm

A couple notes: ppm is an approximation of milligrams/liter, mg/l, which is the more commonly reported unit. The USDA, NRCS (formerly SCS), Montana Technical Note Environment No. 18, issued January 1982, cites the same standards as above, except where noted and references the Environmental Studies Board, Nat. Acad. Sci., Nat. Acad. Eng. Water Quality Criteria 1972.

With regard to saline water, the measure commonly referred to is the Total Dissolved Solids (TDS), which is approximated with the specific or electrical conductance, as measured in either micromohs/cm or deceseimens/meter. The criteria reported were as follows for saline water:

Specific conductance:

?? Less than 1,500 umhos/cm or TDS less than 1,000 mg/l—relatively low level of salinity; excellent for all classes of livestock.

?? 1,500-5,000 umhos/cm or TDS of 1,000—3,000 mg/l - satisfactory for all classes of livestock; may cause temporary, mild diarrhea in livestock not accustomed to the water.

?? 5,000-8,000 umhos/cm or TDS of 3,000-5,000 mg/l—satisfactory but may cause temporary diarrhea or be refused at first; poor quality for poultry.

?? 8,000-11,000 umhos/cm or TDS of 5,000-7,000 mg/l—can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses; avoid using with lactating animals.

?? 11,000-16,000 umhos/cm or TDS of 7,000-10,000 mg/l—unfit for poultry and swine; considerable risk for lactating livestock; should be avoided although older ruminants, horses may subsist on water of this quality under some circumstances.

?? 16,000 umhos/cm or TDS > 10,000 mg/l—unacceptable.

NOTE: conductance is sometimes reported as mmhos/cm, which is umhos/cm divided by 1000. To convert to umhos/cm, multiply mmhos/cm by 1000.

In Montana, the most commonly encountered problems are total dissolved solids, alkalinity, and nitrates. The basic rule in Montana is that livestock should not be watered with water which has a TDS > 10,000 mg/l and/or nitrate+nitrite > 100 mg/l.

Two other references which I found, and which state much the same as the above, are:

Soltanpour, P.N., and W. L. Raley. 1982. Evaluation of drinking water quality for livestock. Service In Action, Colorado State University Extension Service Quick Facts No. 4.908.

Jackson, G., B. Webendorfer, R. Hall, J. Crowley, and D. Keeney.1983. Nitrate, groundwater and livestock health. University of Wisconsin Cooperative Extension Fact Sheet G3217. (Contact Agricultural Bulletin Bldg, 1535 Observatory Drive., Madison, WI 53706. Phone 608-262-3346).

SOME GUIDELINES FOR IRRIGATING WITH SALINE WATER AGRONOMY NOTES NO. 155

http://scarab.ms u.montana.edu/Agnotes/category_294.htm

The quality of water from Montana's rivers and streams generally decreases as the irrigation season progresses. Historic records indicate that sediment load is usually heaviest during the May and June snowmelt runoff periods and as the sediment load decreases and stream volumes decrease, the salt level of most rivers and streams increases. This is particularly true to the streams and rivers east of the Continental Divide. With that being the case, a few guidelines for irrigating with salty water might prove useful for irrigators—especially those using water from the Powder, Milk, Marias, Tiber, Musselshell, Tongue Rivers and secondary tributaries to the Missouri and Yellowstone Rivers.

Irrigating with saline (salty) water. The smaller rivers that supply most of the irrigation water for the eastern two-thirds of Montana are interesting—the saline and volume change dramatically during the year. Review of the historic water quality and flow records indicate several changes through the year. Knowledge of these changes may be of some value in attempting to "get the most" our of the available irrigation water.

?? Fill the profile as early as possible after the peak flood stage or as soon after harvest as possible, if you are harvesting forages (hay, alfalfa). The sediment and salinity levels tend to increase beginning early in the spring as runoff begins. Salinity level peaks and then starts to decrease as dilution takes over, while sediment continues to increase. During the high flow period salinity is low, but sediment is high. Sediment generally tends to start decreasing dramatically after the peak.

?? If at all possible, delay irrigation until after the peak flow period, as the flow level begins to drop. Salinity and sediment tend to be lower at this flow rate on the "down" or falling stage than the same stage on the "up" or rising level part of the cycle.

?? Some sediment in the water will help move the advancing wetting front across border-dike, graded border, basin, and furrow irrigated fine sandy loam soils.

Salinity (or salt load) is best determined by measuring the TDS (total dissolved solids) or EC (electrical conductivity). The TDS varies from as low as only a few hundred parts per million (or milligrams per liter), to as much as 2500 to 3000 parts per million (mg/l) during the lowest flow periods in some of the smaller streams of eastern Montana. The lowest TDS usually occurs when the river level has risen to its maximum and is then falling. When the river goes through ris ing and falling stages due to rain (especially thunderstorms), the TDS is usually lower at a given river level when the level is falling, rather than rising.

Irrigation strategies to reduce salt load. If possible, when irrigating in the spring and early in the irrigation season, fill the profile with water of low TDS/EC. The EC of the water will generally be between 0 and 9 mmhos/cm (equal to 9000 micromhos/cm). To convert this value to an approximate TDS (total dissolved solids), multiply the EC in mmhos/cm by 640. The result will be an approximate TDS in milligrams per liter. The soil will tend to concentrate salt during the irrigation season and thus have an EC greater than the irrigation water. In well-drained soils, the EC will be about the same all the way through the root zone, while on poorly drained soils, the EC will generally increase dramatically with depth. Young plants and seedlings are much more sensitive to EC of both the irrigation water and soil than established plants. Once the EC gets above about 2.4 mmhos/cm in the soil, plants will begin to show signs of stress—stress that looks just like drought.

Irrigation strategies to reduce salt injury to seedlings. On new plantings of alfalfa, grass, other legumes, small grains, corn, and sorghum, shorten the length of time or your sets early in the season, when plants are still small, and irrigate just a little more frequently. You'll pump just the same amount of water as before, but get a better stand, better early growth, and an increase of as much 25% in overall yield. In addition, the irrigation water will tend to have slightly less dissolved salt this time of the season. Use of saline water for irrigation. The following is a summary of an article by J. D. Rhoades, soil scientist with the U.S. Salinity Lab in Riverside, CA. The article first appeared in the October 1984 issue of California Agriculture. Saline water, or water which is generally classified as having too much dissolved salt for irrigation, can often be used successfully without hazardous long-term effects on the crops or soils. However, certain conditions need to be met:

?? The soil being irrigated must be well-drained

?? Salt tolerant crops (established alfalfa, barley, sorghum, sudan grass, sordan) should be the primary crops grown

?? Rotations should be planned to provide for a sequence of progressively more salt tolerant crops

?? Salts should be leached out of the soil in the spring or winter

?? As the salinity of either the irrigation water or soil solution increases (with prolonged crop water use and through the irrigation season), the volume of irrigation water applied should be progressively increased.

As Rhoades points out, adoption of new crop and water management strategies can further facilitate the use of saline water for irrigation. One strategy is to substitute more saline water (later in the irrigation season) for good quality water to irrigate certain crops in the rotation or well-drained soils. Whatever salt buildup that might occur in the soil from irrigating with salty water can be reduced in the following winter or spring from rainfall or irrigation with low-salinity irrigation water.

Soils do not usually become excessively saline from use of saline water in a single irrigation season. It may even take several irrigation seasons to affect the level of salt in the soil solution. The maximum soil salinity in the root zone that results from continuous irrigation with saline water does not occur when salty water is used only a fraction of the time.

For purposes of comparison, Colorado River irrigation water has a TDS of about 900 ppm, while the rivers of central and eastern Montana generally ranges from about 750-1,500 ppm during the irrigation season. Drainage water TDS will usually be 3,500 to 4,500 ppm.

SOIL SALINITY CROP AND FORAGE TOLERANCES
AGRONOMY NOTES NO. 170

http://scarab.msu.montana.edu/Agnotes/category_295.htm

Occasionally, I will get a phone call from someone wanting to know about tolerance of various crops and plants to salinity. Generally, I try to preface my comments about crops with a few words about salinity. There are two sources of salts which appear in the soil: either from the soil itself or from irrigation or drainage water. In either case, the presence of saline conditions in the soil indicates 'inadequate' drainage, either due to very slow percolation rates, high water table, not enough water to cause leaching, or upward water movement. The essential requirement for mediating a salinity problem is three-fold: 1) improve the drainage such that the excess salts can be removed; 2) remove or reduce the source of the salinity, i.e., either shut off the water or reduce the amount of water being applied so that excess water is not present, and 3) add sufficient good quality water to leach the existing salts.

After this little speech, the individual calling usually asks "what crops can I grow in salt-affected soil?" The logical answer is 'salt-tolerant crops'. And, "those would be....?"

The following is a list of commonly grown crops, presented from most tolerant to least tolerant, with respect to salinity. The number beside each crop is the EC (electrical conductivity) of a saturated extract from the soil that the crop will 'tolerate' in the mature stage.

barley	8.0 mmhos/cm
sugar beets	7.7 mmhos/cm
wheat	6.0 mmhos/cm
safflower	5.3 mmhos/cm
soybeans	5.0 mmhos/cm
sorghum	4.0 mmhos/cm
corn	1.7 mmhos/cm
flax	1.7 mmhos/cm
field beans	1.0 mmhos/cm

For a complete listing and reference to salt tolerant crops, see the "Western Fertilizer Handbook", pages 30-35. Another one of those excellent reference books written for farmers.

The other question that comes up is something like this: "I have a saline seep which I have been trying to reclaim. What forage crops can I grow in the salt-affected area?" The answer to that question again depends on the soil conditions. However, the list of tolerant forages is pretty well defined. It looks like the following, from most tolerant to least tolerant:

tall wheat grass	7.5 mmhos/cm
wheat grass (fairway)	7.5 mmhos/cm
bermudagrass	6.9 mmhos/cm
hay barley	6.0 mmhos/cm
perennial ryegrass	5.6 mmhos/cm
birdsfoot trefoil	5.0 mmhos/cm
harding grass	4.6 mmhos/cm
tall fescue	3.9 mmhos/cm

Comment: seedlings are generally much more sensitive to salinity than established plants.

crested wheat grass	3.5 mmhos/cm
vetch	3.0 mmhos/cm
sudan grass	2.8 mmhos/cm
big trefoil	2.3 mmhos/cm
alfalfa	2.0 mmhos/cm
berseem clover	1.5 mmhos/cm
orchardgrass	1.5 mmhos/cm
meadow foxtail	1.5 mmhos/cm
clover: alsike, ladino red, strawberry	1.5 mmhos/cm

As an approximation, you can assume that the yield of each of these forages and the previous crops will be reduced by 10-15% if the conductivity is increased 25%, 25-35% if the conductivity is increased 50%, and 50% or more if the conductivity is doubled.

So, the next time you suspect you have a salinity problem, collect a soil sample, send it to a lab and ask for the EC (electrical conductivity or conductance), the pH (an index of salinity), and the SAR—the sodium adsorption ratio. With that information and the list provided here, you should be able to decide what is the best cropping strategy for your situation.